A Basic Study about Multi Channel Measurment of Skin Impedance Vector Loci on the Acupunctur Points

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Abstract— **Acupuncture points have been found to be the points of low electrical resistance compared to the surrounding tissue. The significance and detail of the singular electrical properties of acupuncture points are uncertain at present. In this report, we measured the absolute value and the phase of skin impedance on an acupuncture point and non-acupuncture point at many frequencies and current values. Absolute value, phase and vector loci of skin impedance showed dependencies on the amplitude of applied current. So, we examined how the current dependencies changed according to test subject and measuring points. As a result, for performing reliable measurement of skin impedance vector loci, we found that the suitable frequency range of applied current to the skin is from 10 to 400 Hz and we need to determine the current value for each measurement. Additionally, we applied those results to 4 channel measurements of skin impedance vector loci around the acupuncture point under the condition that the room temperature and humidity were kept constant.**

Keywords— **acupuncture points, skin impedance vector loci, current dependency of skin impedance**

I. Introduction

Acupuncture points are important in acupuncture and moxibustion therapy. They have been found to be points of low electrical resistance compared to the surrounding tissue[1][2]. The significance and detail of the singular electrical properties of acupuncture points are uncertain at present.

Most published studies about electrical properties of acupuncture points have been performed using direct current(voltage) or using polarized electrodes etc[3][4][5]. More careful consideration of the electrical properties of the skin and reliable measurements were needed. In order to improve the reliability of the measurements and to make the electrical properties of the skin around the acupuncture points clear, we examine a suitable measurement method and condition.

Measurements of skin impedance are neccesary for detailed analysis of electrical properties of the skin. The problems with measuring skin impedance have been pointed out in previous research; for example: electrical break down of skin[3][6], the pushing pressure of the electrodes[6], current and voltage dependency of skin impedance[7] and so on. Our goal is to clarify the electrical properties of the skin around the acupuncture(low electrical resistance) points by multi channel measurements of skin impedance vector loci. At first, we must examine a measurement method and condition carefully enough for obtaining reliable measurements.

In this reports, we measured the absolute value and the phase of skin impedance on an acupuncture point and non-acupuncture point at many frequencies and current values. The vector loci of skin impedance showed dependencies on the current. So, we examined how those current dependencies changed according to the test subjects and the measuring points. As a result , to perform reliable measurements of skin impedance vector loci, we found that the suitable frequency range of applied current to the skin is from 10 to 400 Hz and we need to determine the current value for each measurement we performed.

Additionally, we applied the obtained results to 4 channel measurements of skin impedance vetor loci around the acupuncture point under the condition that the room temperature and humidity were controlled.

II. Methods

The experiments were performed on 6 healthy human subjects(all men, aged 22 to 26 years). The measurement locations were two points. One was at an acupuncture point called "Quchi(LI_{11})" at the left arm and another was at a non-acupuncture point that is 20 mm away from Quchi (Fig.1). Pre-gelled Ag-AgCl electrodes(Nihonkoden, P-150, area = $1cm^2$) were used and the 3-electrode technique[8] was used.

The measurement of impedance was performed by

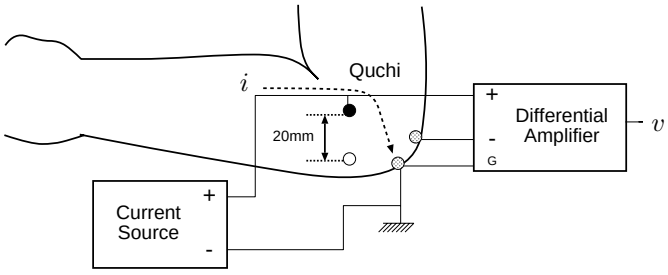

Fig.1. The measurement locations of skin impedance. One was at an acupuncture point called "Quchi(LI_{11})" at the left arm(●) and another was at a non-acupuncture point that is 20 mm away from Quchi (○).

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Abstract

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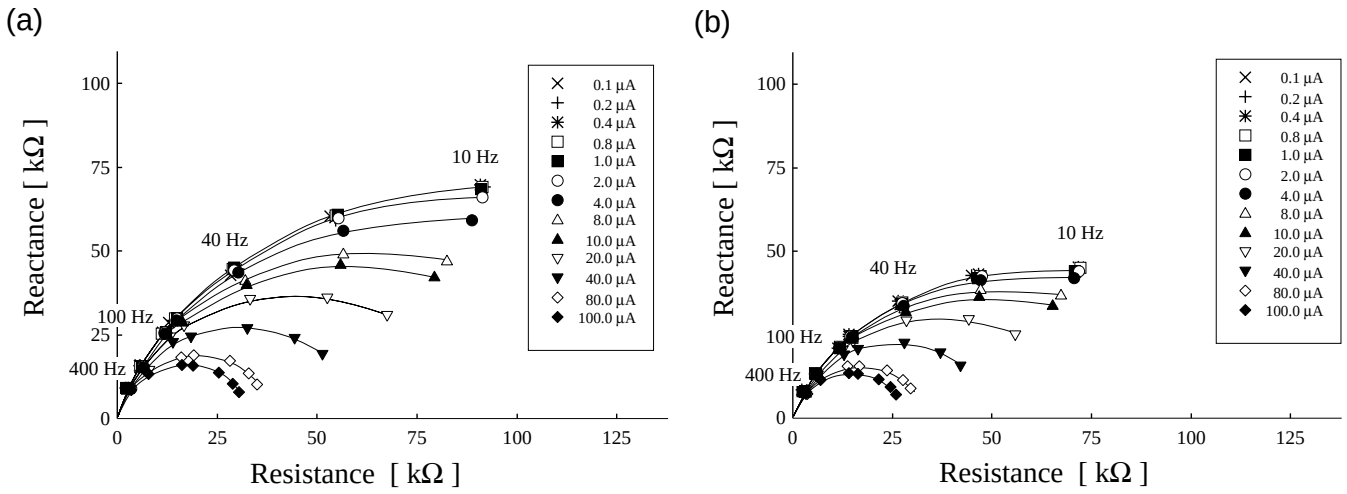

Fig.2. A typical example of the current dependency of the skin impedance vector loci(Subj.A.). (a) Non-acupuncture point, (b) Acupuncture point(Quchi).the current dependency disappears below 2.0 μA on Quchi and 1.0 μA on non-acupuncture point. There is a remarkable current dependency at low frequencies, but at high frequencies, it is slight.

constant-current method with a sinusoidal current. The current values were 0.1, 0.2, 0.4, 0.8, 1.0, 2.0, 4.0, 8.0, 10.0, 20.0, 40.0, 80.0, 100.0 μA amplitude. The mearurement frequencies were 10, 20, 40, 80, 100, 200, 400 Hz.

The current values were increased from 0.1 μA to 100 μA gradually, and we measured the absolute value and the phase of impedance at all measurement frequencies with a lissajous figure[9], and we calculated the real part and the imaginary part of the impedance and finally obtained the impedance vector loci at all current values. It is reported that the skin impedance and its vector loci show a current dependency[7]. So, we examine how those current dependencies changed with different test subjects and the measuring points.

All measurement started 20 minutes after the electrode was applied to the skin to obtain stable contact status between the electrodes and the skin.

III. Result and Discussion

A. *The suitable current value and the frequency range to perform reliable measurement*

Fig.2. shows the impedance vector loci of an acupuncture point called "Quchi" and of a non-acupuncture point for all current value. These loci show a dependency on the current, but all frequency points fall onto a circular arc. In this case, the current dependency disappears below 2.0 μA on Quchi and 1.0 μA on non-acupuncture point. As shown in Fig.2., there is a remarkable current dependency at low frequencies , however at high frequencies, it is slight.

The impedance vector loci at all current values on non-acupuncture points were larger than that on Quchi. Additionally, its difference becomes more markedly at low frequency range.

There was a similar tendency for all subjects. T. Yamamoto and Y. Yamamoto [7] reported that the current dependency is more apparent with a large current, at a lower frequency and at higher impedance. Our result does not contradict their one. However, the difference between impedance loci on Quchi and that on non-acupuncture point changed according to the test subject. Additionally, the current value at which the current dependency disappears, changed according to the test subject and the measuring points. Accordingly, the current value should be as small as possible. However, measurements with extremely small current result in small signal-to-noise ratio. For reliable measurements, we need to determine the current value range, in which current dependencies does not appear, for each measurement we perform.

The measurement frequency range should include low frequency as much as possible because, as shown Fig.1, at low frequency range, there is a remarkable difference between the impedance locus of an acupuncture points and that of a non-acupuncture points. But at d.c. or extremely low frequency range, current dependency will become remarkable and many phenomena such as polarization of an electrode, electrodermal activity and so on, can cause problems in measurement. Accordingly, the lower limit of measurement frequency should be above 10 Hz that we used in this report. The upper limit of measurement frequency is around 400 Hz, because, as shown in Fig.2., there is negligible differences at high frequencies.

B. *An application example of the result – 4 channels measurments of skin impedance vector loci around the acupuncure point –*

We applied the results to 4 channels impedance meaurements around acupuncure points.

The experiments were performed on one healthly human subject (man, aged 23 years). The measurement lo-

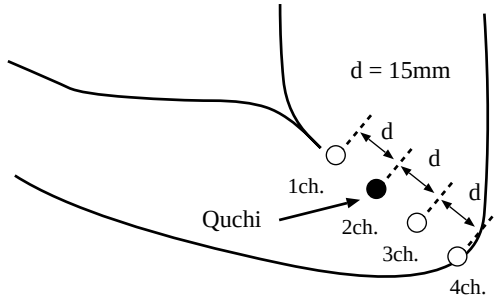

Fig.3. The measurement locations in an application example of the result. The measurement location were at an acupuncture point "Quchi" at the left arm(●)and at three non-acupuncture points(○). Quchi corresponded to 2ch.

cations were an acupuncture point "Quchi" at the left arm and three non-acupuncture points(Fig.3.). An acupuncture point "Quchi" corresponded to 2ch. The absolute values and the phases of impedance at all points were measured with the same electrodes and the same method that we used in the previous experiment. The real part and the imaginary part of impedance were calculated and finally we obtained the skin impedance vector loci.

According to the results in previous section, the measurement frequencies were 10, 20, 40, 80, 100, 200, 400 Hz and the current value was determined so that current dependencies do not appear at all. In this case, it was 0.4 μA amplitude. Additionally, in this experiments, the room temperature and humidity were controlled to be constant at 21.0 °C and 39 % constant, in oder to avoid that temperature, humidity and sweat affect the skin impedance[11][12]. And the measurement started 20 minutes after the electrode was placed to the skin to obtain stable contact status between the electrodes and the skin.

Fig.4 shows the skin impedance loci at all measurement points. On each measurement point, all frequencies points seemed to fall onto a circular arc. However, the impedance vector loci on each measurement point were different. The impedance vector loci on 2ch. and 4ch. were smaller than those on the other points.

It is known that the skin impedance satisfies the circular arc law[10], as impedances of various biological tissues also do. The skin imedance $Z(\omega)$ can be expressed by

$$Z(\omega) = Z_\infty + \frac{Z_0 - Z_\infty}{1 + (j\omega\tau_m)^\beta}$$

where $Z_0 = \lim_{\omega\to 0} Z(\omega)$ and $Z_\infty = \lim_{\omega\to\infty} Z(\omega)$. The parameter β express the deviation from the Debye system, and τ_m is the central relaxation time.

For evaluating the differencies of impedance vector loci quantitatively, we estimated these parameters of the skin impedance with non-linear least-squares fitting

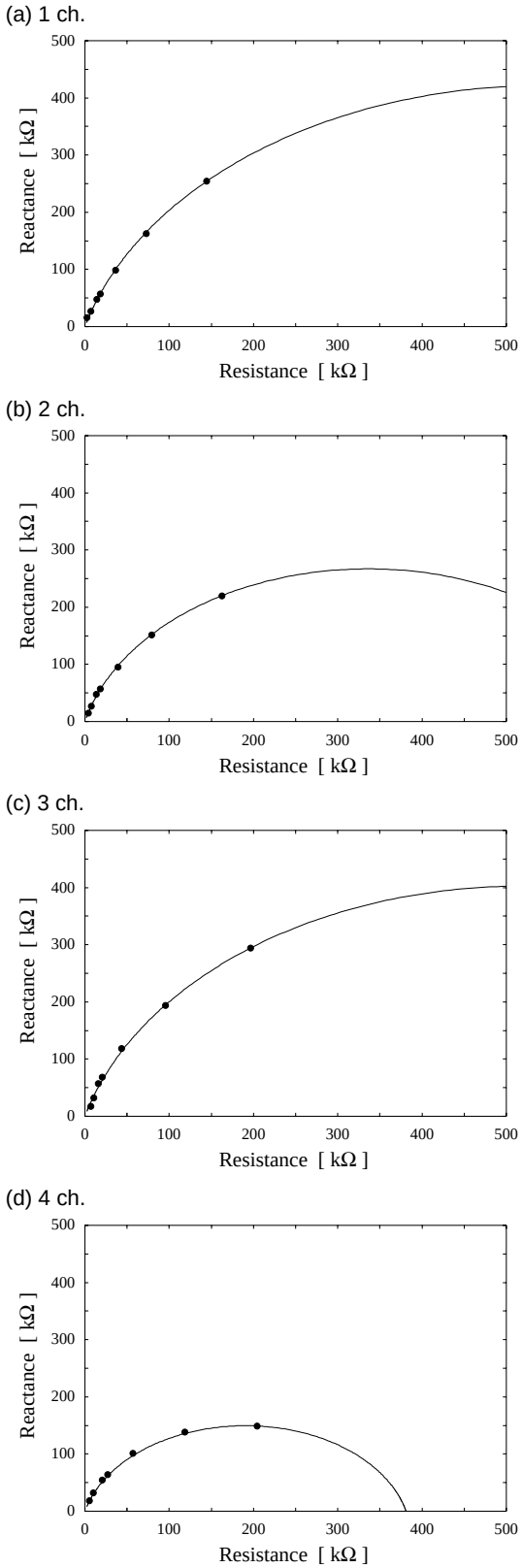

Fig.4. Skin impedance vector loci around the acupuncture points. (b) cooresponed to vector loci of "Quchi". The impedance vector loci on each measurement points were different. The vector loci on 2ch. and 4ch. were smaller than those on the other points.

TABLE I

The estimated value of skin imedance parameter at each measurement points.

Point	Z_0 [kΩ]	τ_m [ms/rad]	β
1ch.	1090.6	0.067	0.838
2ch.	672.59	0.036	0.854
3ch.	1040.5	0.048	0.839
4ch.	381.07	0.014	0.847

(Levenberg-Marquardt method)[13] from vector loci on each measurement point.

Table.I. shows the parameters of the skin impedance at all measurement points. The parameter Z_∞ was neglected because the precision of measurement results at high frequencies was not adequate and as shown Fig.4., Z_∞ was usually slight.

As shown in Fig.4. and Table I, the differencies of imedance loci, that is, detailed electrical properties of skin can be evaluated by quantitatively by the skin impedance parameter. Howevwer, more experiments as shown in this section need to be done to discuss about the differenceies of skin imedance loci or impedance parameter between an acupuncture point and non-acupuncture point.

IV. Conclusion

In this report, we measured the absolute value and the phase of skin impedance of an acupuncture point and a non-acupuncture point at many frequencies and current values. We found that vector loci of skin impedance showed dependencies on the current and those current dependencies changed according to the test subject and the measuring points. Accordingly, for performing reliable measurement of skin impedance vector loci, the suitable frequency range of the applied current to the skin is from 10 to 400 Hz and we need to determine the current value range in which current dependencies do not appear, for each measurement we perform.

Additionally, we applied the results obtained to perfoming 4 channel measurments of skin impedance vector loci around the acupuncture point under the condition that the room temperature and humidity were controlled. More experiments need to be done to discuss about the differenceies of skin imedance loci or impedance parameter between an acupuncture point and non-acupuncture point.

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